printed on one side of the paper only, for the use of librarians. The price to subscribers of each copy in this form will be 20*s.*, delivered post free in the United Kingdom, and plus the extra postage for abroad. The price of the catalogue in the ordinary form will be 16*s.* The importance of this enterprise, not only to science but to bibliography generally, need not be insisted on. Those interested should communicate with the Librarian of the Society, 4, Broad Sanctuary, Westminster, S.W.

A LARGE coal-field, we learn from the Sheffield *Daily Telegraph*, has just been opened out near Hemsworth, about seven miles from Barnsley. The thick or Barnsley seam of coal has been reached on the estate of Mr. Allott, at a depth of 635 yards from the surface. This proves that a well-known and valuable bed exists in what may be termed the largest unworked coalfield in the West Riding. The shaft is the deepest in South Yorkshire, and the field in which the seam is worked commences at its southern extremity close to the town of Nottingham, and extending through Derbyshire, proceeding along the margin of the limestone to Barnsley and the east of it and the Ashworth Rock. The great coal-field, which includes parts of Derbyshire, Yorkshire, and Notts, is the largest in England, and only 150 square miles less in area than that of South Wales, the extreme length being sixty-six miles. The southern boundary is new red sandstone, and the strata rise and cross out westward near Bradford and Leeds, and then turning to the east, disappear under the magnesium limestone. The thickness of the bed near Hemsworth is about eight feet, which may be considered as about the average in South Yorkshire, while at Shireoaks Colliery, near Worksop, it is little more than three feet. The new colliery will be able to raise, when fully opened out, more than 1,000 tons daily, so that there will be an addition to the coal-producing power of South Yorkshire of 400,000 tons a year.

THE possibility of keeping a manatee in a healthy state in an aquarium is fully proved by the good condition of that at Westminster. It arrived on June 20, and has increased in size and done well. The only other specimen brought alive to England lived at the Zoological Gardens from August 6 to September 7 only, in 1875. At Westminster the animal is in a glass tank above the level of the ground, and accessible on both sides, so that its movements, position in floating, &c., can be well seen.

THE *Times*' notice of Bank Holiday amusements speaks of the Nubian Camp at the Alexandra Palace as an educational entertainment. In this we quite agree, and hope that every success may attend such instructive exhibitions as this.

RESPECTING the tornado, by which Canton was visited on April 11, the Rev. John Chalmers writes to the London Missionary Society that after careful inquiry and personal observation, he concludes that the whirlwind did not extend much further than three miles, the average width of its path being about three hundred yards. But on the next two days there were several distinct whirlwinds of a similar character in the neighbourhood. Over the space above indicated the tornado seems to have equalled in force and destructive effect anything of the kind heard of in the West Indies.

IN our "Meteorological Notes," vol. xviii. p. 287, the name of Mr. Eliot, who is officiating for Mr. H. F. Blanford in India, during the absence of the latter, should have been quoted instead of that of Mr. Blanford, as the authority for the forecast of the monsoon referred to.

AN astronomical correspondent suggests that in Mr. Lockyer's Eclipse telegram last week the words "Corona probably photographed in Siam. Fluorescent eye-piece worked well," should read "Corona probably photographed; it seemed fluorescent. Eye-piece worked well." With respect to the place of "Vulcan" as observed by Watson, R.A. 8° 26′ should be R.A. 8h. 26m.

THE additions to the Zoological Society's Gardens during the past week include a Slow Loris (*Nycticebus tardigradus*) from Borneo, three Chinese Cranes (*Grus longirostris*) from China, presented by Mr. Theodore Hance; a Mexican Deer (*Cervus mexicanus*) from Mexico, presented by Mr. A. Scrutton; a Common Fox (*Canis vulpes*), European, presented by Mr. Athelston Riley; three Great Bustards (*Otis tarda*) from Spain, presented by Lord Lilford, F.Z.S.; a Tiger Bittern (*Tigrisoma brasilianea*) from South America, presented by Mr. Hammond Hawbyne; a Greater Sulphur-crested Cockatoo (*Cacatua galerita*) from Australia, presented by Mrs. A. A. Hole; a Passerine Owl (*Glaucidium passerinum*), a Bacha Eagle (*Spilornis bacha*) from Borneo, presented by Mr. J. S. Jameson; two Beisa Antelopes (*Oryx beisa*) from North-East Africa, a Brown Coati (*Nasua nasica*) from America, deposited; an Ocelot (*Felis pardalis*), a Black Vulture (*Cathartes atratus*) from America; two Chilian Sea Eagles (*Geranoaëtus melanoleucus*), a Brazilian Caracara (*Polyborus brasiliensis*) from South America, two Rufous Tinamous (*Rhynchotus rufescens*) from Brazil, nine Spotted Tinamous (*Nothura maculosa*) from Buenos Ayres, a Razor-Billed Curassow (*Mitua tuberosa*) from Guiana, purchased; an Axis Deer (*Cervus axis*), born in the Gardens.

THE PHONOGRAPH AND VOWEL-SOUNDS[1]

II.

IN our last communication we confined our attention to the letter ō. We will now turn to the letter ū (corresponding to *oo* in "food"). Fig. 2 shows a series of curves obtained for

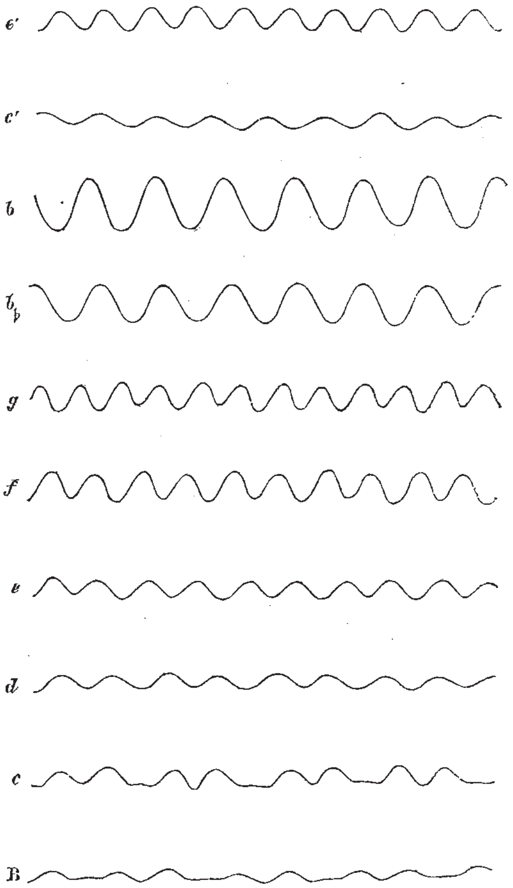

FIG. 2.—*Wave-forms of ū Sung by the same Voice at Various Pitches*

ū by the mechanical process already described. They are all sung by one voice: that numbered 5 in our previous communication.

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[1] Continued from p. 343.

Table V. gives the amplitudes of the first six harmonic partial tones for this series; and Table VI. gives the same constituents of another series of ū's, sung by the voice formerly numbered 1.

Comparatively few curves have been transcribed for the sound ū, because the groups of constituents in this letter are much simpler than those in ō. Moreover, although the curves for only two voices have been analysed, we have by numerous examples satisfied ourselves that the selected examples represent with sufficient accuracy results produced by several other voices.

In examining Fig. 2 it must be borne in mind that the phonograph was turned in all cases at approximately the same speed, as accurately as this could be done by aid of a metronome. The length of the period in the curve corresponds, therefore, to the duration of the vibration which the voice produced on each note. On the upper path of the scale the wave-forms are almost exactly simple harmonic curves, but from *g* down to *d* the period is composed of two halves each closely resembling a simple harmonic curve, so that the form on *e*, for example, is not readily distinguished by eye from that on *e′*, an octave higher. Below *d* the curve breaks up into a somewhat irregular triplet.

Table V.—*Harmonic Constituents of ū Sung at Various Pitches by Voice No.* 5.

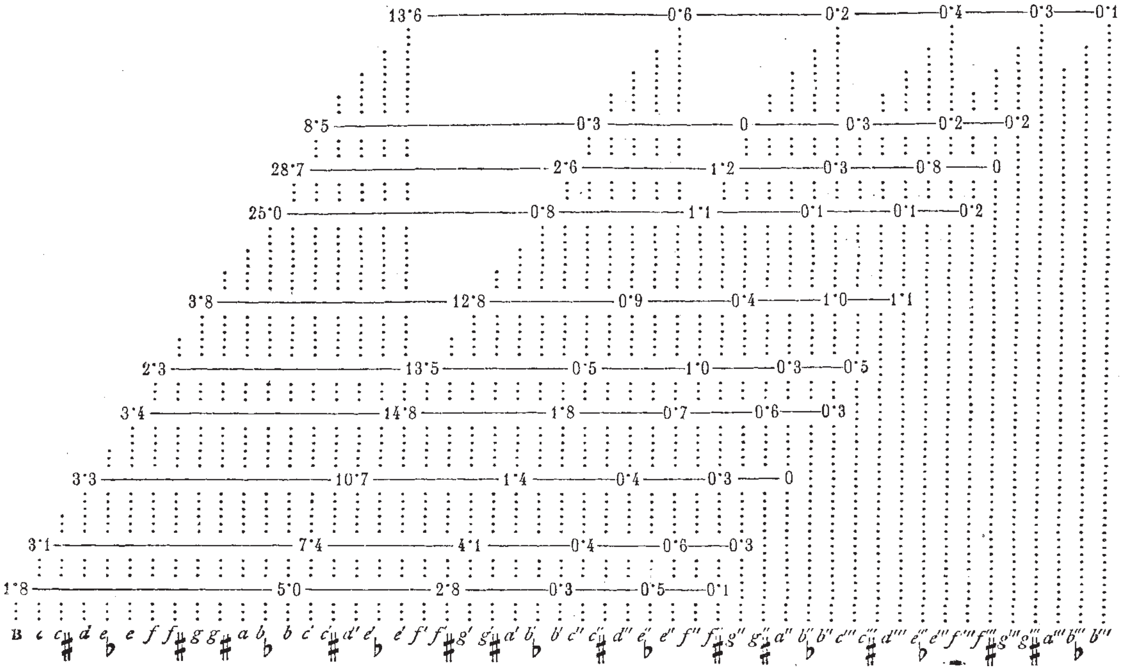
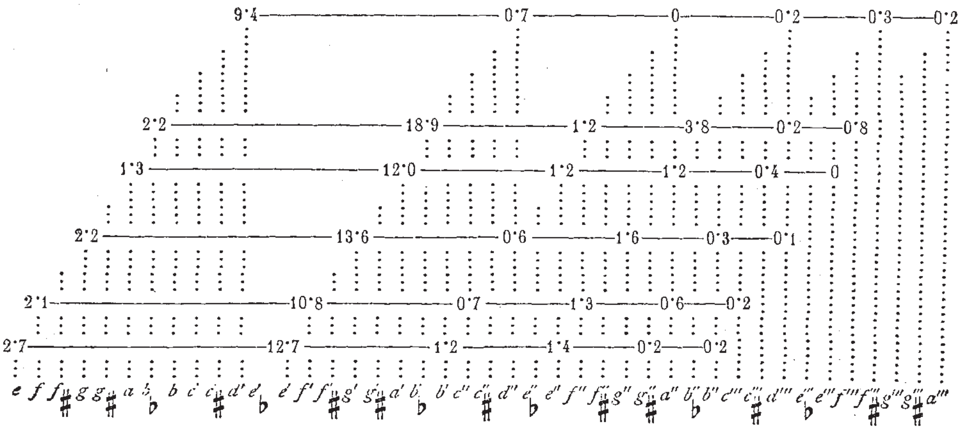


Table VI.—*Harmonic Constituents of ū Sung at Various Pitches by Voice No.* 1.



We will call the curves for the notes above *b*♭ *simple ū* curves, and those from *g* downwards *duplex ū* curves. The analysis of the duplex curves shows that they consist of a very weak prime tone with an immensely strong second partial. The figures and tables might easily be extended above *e′*, but it is unnecessary to continue them, for the higher notes all give the same close approximation to the simple harmonic wave. We cannot say that we have obtained a good ū below *d* from any voice. The marks on the tinfoil were always feeble, and the sound as repeated by the phonograph was little more than an inarticulate groan. It will be observed that the note *a* is wanting in the tables and in the figure. It has been omitted because we had difficulty in getting a good ū back from the phonograph when the vowel was sung on this note. We have no doubt a good ū can be pronounced at this pitch, but we observed a constant tendency towards the ō character both in the curves and in the sound; that is to say, there was a tendency to give the two lowest partials instead of a simple prime, or a strong second and very weak prime. Moreover, the curves would vary in character during the utterance, which was seldom, if ever, the case at other pitches, indeed, the constancy of the wave-forms produced by the voice over hundreds of periods has usually been very striking.

In order to maintain the ū quality throughout a series of ū's, the change from the single to the duplex form had to be quite abrupt. To test the ū at this critical point *slurs* were executed by voice 5 both up and down; that is, attempts were made to continue to say ū, and at the same time gradually raise and lower the pitch past *a*. At this pitch one of two things invariably happened. Either the curves became so like those for ō that they could not be distinguished from ō at the same pitch either by eye or ear, or they sunk to such an insignificant size as to indicate an interval of almost total silence.

TABLE VII.—*Harmonic Constituents of ō Artificially Produced at Various Pitches.*

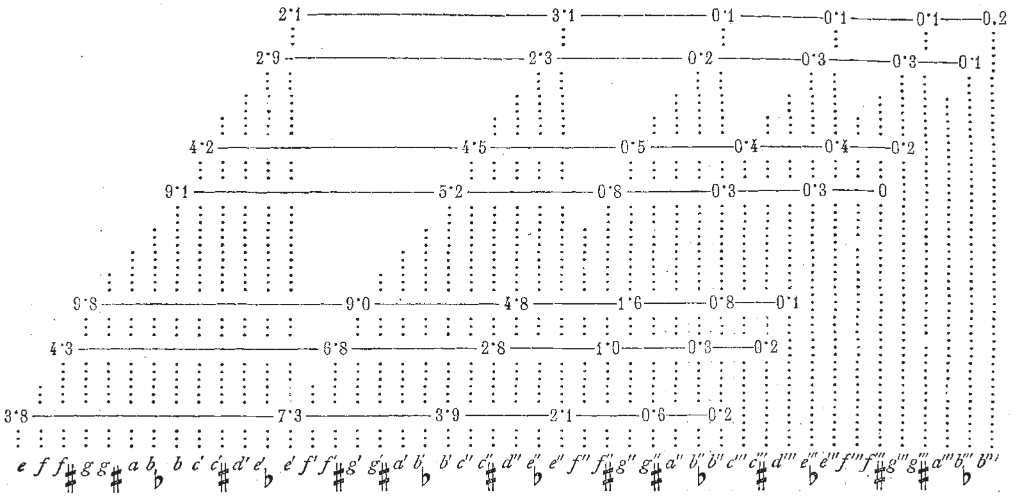


TABLE VIII.—*Harmonic Constituents of a° Sung at Various Pitches by Voice No. 5.*

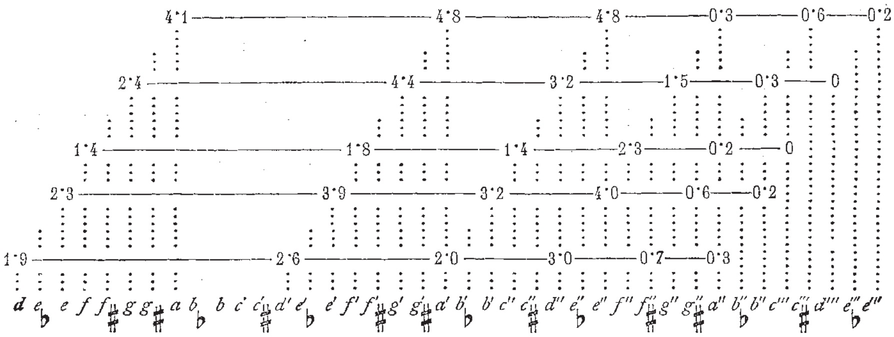
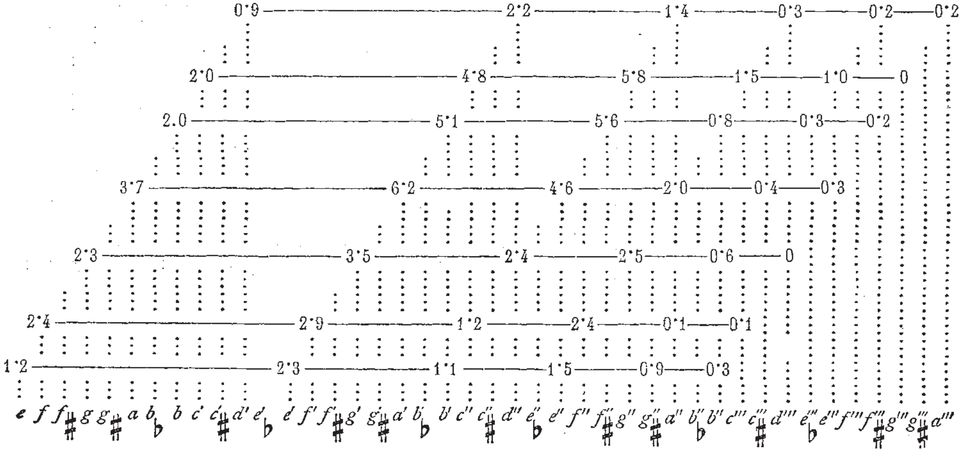


TABLE IX.—*Harmonic Constituents of ā Sung at Various Pitches by Voice No. 5.*



One voice (No. 7) carried the simple harmonic form of ū down as low as *f*. This voice had a very limited range, and could not produce the duplex form at all. Moreover, the sound of the simple ū, while being spoken on *f* or *g*, was less vocal and more like a whistle than the duplex ū given by other voices.

One and the same voice, when singing on *a* or *b*♭, would sometimes give the simple and sometimes the duplex form.

The following general propositions are, we think, established by these experiments:—

1. The generic character of *ū* from *d* upwards is given by the prominence of a single partial tone. Above *b*♭ this partial is the prime. Below *a* with certain voices it is the octave of the prime.

2. The amplitude of the second partial is sometimes as much as nine times greater than that of the prime, but the sound will be recognised as *ū* when the second partial is only three or four times the size of the prime, provided the pitch of the prime is below *a*.

3. Below *d* the experiments do not warrant positive conclusions. The prominence of a single partial is less marked, and at the same time the vowel quality of the spoken sound is very poor.

4. The average pitch of the reinforced tones is generally lower than the average pitch of the group for *ō*.

5. We have not detected any single note having the marked characteristics for *ū* that were possessed by the note *b*′♭ for *ō*.

6. There is a critical pitch in the neighbourhood of *a* or *b*♭, at which a sudden change takes place in the wave-forms given by certain voices in singing *ū*. Further experiments are desirable in this sound at this pitch. The critical pitch is not perfectly constant for a single voice.

As some doubt may not unnaturally be felt whether or not the singular change of character observed in *ū* at or near the note *a* may not have been due to some peculiarity of the instrument, we may repeat that, being fully aware of this danger, we tried the experiment repeatedly with changed mouth-pieces, changed vibrating discs, changed springs, and with different thicknesses of tin-foil, but invariably with the result that certain voices passed at this pitch from the simple to the duplex *ū*. It must not be forgotten, too, that one voice, using the same instrument, carried the simple *ū* as low as *f*.

7. This points to the fact that the change from simple to duplex *ū* is not made on account of the requirements of the ear, but on account of the difficulty in adjusting the mouth-cavity so as to continue the simple form on the lower notes. We have seen that, not only do different voices make the change at different pitches, but a single voice gives sometimes one and sometimes the other form at pitches near its critical point. We thus see that the simple and duplex forms overlap, and that in this case sounds of the same pitch, which differ by a whole octave in the pitch of their single prominent tone, are accepted by the ear as generically the same vowel.

The prominent tone in *ū* is found to lie in the region from *a* upwards, but we have not found any one sharply-defined pitch to be characteristic of *ū*.

With reference to the theory of characteristic tones in vowel-sounds we draw attention to the very great prominence of the tone *b*′♭ (the characteristic tone of *ō*) when voice 1 sang *ū* or *b*♭. What may be termed the average pitch in *ū* is for notes near *d* and *e* lower than that in *ō*, owing to the absence of the third partial; but it is noteworthy that, as the voice runs up the scale, the constituents of *ū* are on an average higher than those of *ō* for *g*, and in the case of voice 1 even for *b*♭; this arises from the comparative smallness of the prime. When the simple form is reached the average pitch of the constituents is lower than that for *ō*. If, instead of looking at the average pitch, we look at the pitch of the highest and most prominent constituent, we find that this pitch is identical for *ū* and *ō* when these vowels are sung on *g* by voices 1 and 5, and when sung on *b*♭ by voice 1.

Further light is thrown on the whole theory of vowels by experiments on the vowel *ō* as uttered by a mechanical contrivance made by Prof. Crum Brown and lent by him to us for investigation by help of the phonograph. It consisted of a bag-pipe reed fitted to a tube leading into a gutta-percha resonance chamber which had such a form and such openings (tentatively arrived at) as caused it to speak a very good *ō* when the reed was blown. No one listening to this sound could doubt that the letter *ō* was being distinctly spoken. We held this apparatus to the phonograph, and the record obtained from it gave back a remarkably good *ō*, better indeed than the original, as the jarring noise of the reed was lost. When the pitch of the reed was changed, the same vowel continued to be given. The pitches in our experiments with this resonance bottle ranged from *e* to *e*′. We had thus a constant cavity producing unmistakably the same vowel throughout an octave.

Table VII. gives the constituents of each *ō* thus artificially produced. They agree with the *ō*'s pronounced by the voice in being composed of a prime and its octave for notes above *b*, also in having the first three partials on *e* and *f*♯. On *g* the third is stronger than in the human voice. No specially strong reinforcement appears to exist in this artificial *ō* for *b*′♭, or any tone near it, but there is a wide range of reinforcement extending on both sides of this pitch. It may be stated that this artificial *ō* was what might be called a bright *ō* whose pitch of general or of maximum resonance might be expected to be somewhat higher than that of the *ō*'s given by the human voice.

We draw attention to the fact that even supposing the prime not to have been reinforced at all, this irregular gutta-percha cavity must have reinforced tones, more or less strongly, through a range of at least fifteen semitones, namely, from *e*′ to *g*″. This fact follows from the analyses, but it was confirmed by another and independent experiment. A short tube was inserted into the bottle in place of the reed and the end of the tube applied to the ear so that the cavity acted as a resonator to sounds from outside. The keys of a piano were then struck in succession and the listener noticed by the bumming noise in the bottle what tones were reinforced. On working down the scale resonance was first noticed at *g*″♯. It increased, and became excessively strong on *f*″, and remained nearly equally strong on *e*″. It then diminished a little, but became very intense again on *c*″♯, then diminished again, but even on *g*′ and *f*′♯ it was much stronger than could be accounted for by the strengthening of the second partial. Below this the experiment was not suited to detect the influence of the cavity as a resonator on account of the reinforcement of upper partials in the notes struck. It sufficed, however, to prove that this irregular cavity possessed not only one, but probably several proper tones, so near to one another as to give the effect of a resonator strengthening, more or less, every tone between widely distant limits.

We have also made a few experiments on the vowel sounds "awe" and "ah," which we shall write *a*° and *ā* respectively. The phonograph spoke these sounds fairly well, though not quite so well as the sounds *ō* and *ū*. It may here be remarked that our phonograph was not capable of registering very high tones; a shrill whistle, however loud, produced no effect on the tinfoil. This fact proves, independently of the analyses, that in the case of those vowel sounds which it did speak well, the comparatively low partials were sufficient fully to characterise the vowel. The observations show that for *a*° the first three partials are prominent where *ō* has only two; and that for the same part of the scale *ā* has four consecutive partials all prominent. The fifth partial was considerably strong for *ā* when sung on *e*, where *ō* was composed of three partials and *a*° of four. Tables VIII. and IX. show the analyses made of these two vowels as sung by voice 5.

This communication is already so long that we must defer our general remarks to another number.

FLEEMING JENKIN
J. A. EWING

EXPERIMENTS ON THE RELATIVE SPECIFIC GRAVITIES OF SOLID AND MELTED MATERIALS AT THE TEMPERATURE OF FUSION

DR. MUIRHEAD communicates the following account of experiments undertaken at his request, for the purpose of testing the notion that the earth's crust, as it cooled, became relatively heavier than the molten mass within; that the crust, breaking into fragments, sank; and this process, going on time after time, by and by built up a sort of honeycombed arrangement of the earth's interior:—

"*Railway Works, Leeds*, March 30, 1878

"DEAR SIR,—I have carefully gone over the experiments *re* the melting of metals in contact with liquid metals. I was certain on this point, from more than half a century's observation, before you wrote me, and I think I stated that conclusion in a former letter. I have now only to indicate the order in which I conducted the experiments, the result of which I now communicate.

"With several different compounds of brass, at various temperatures, I melted similar compounds; skimming the metal in the crucible, I laid the solid piece carefully on the clean surface, which piece, coating itself partially by chilling the liquid metal, very soon re-absorbed a sufficient amount of heat to be fused,